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Prehistoric populations from Gua Bedug in the context of early-mid holocene of Java, Indonesia*

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Abstract

Until recently, research on the early arrival of modern humans on the north coast of Java, Indonesia were limited. Previous research has focused more on the southern part of the island. Our research in the karst area of the Rembang Zone in the northern coast of Central Java has recovered human remains that offer potential new insights into the early occupation of Java Island by modern humans, especially during the Early-Mid Holocene. This paper presents the analysis results of 29 dental specimens from Gua Bedug, Rembang Regency. The studies aimed to determine racial affinities based on dental metrics and morphology. The results show that characteristics of the East Asian population were present at Gua Bedug at least from 5.800 BP. Specimens with East Asian characteristics were discovered in the context of Preneolithic culture, along with other specimens that represent Australo-Melanesian characteristics, highlighting the diversity of human inhabitants of the region during that period. The results also suggest that the occupation of the north coast of Java during the Pleistocene-Holocene transition, around 12.000 BP, was more complex than previously thought.

Keywords: dentition; prehistory; affinity; migration; cave site

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Introduction

Java Island is the most densely populated island in Indonesia. This condition has apparently occurred since the beginning of human settlement in prehistoric times thousands of years ago. Archaeological research has proven the existence of a large population of early Homo erectus humans on this island (1) from at least a million years ago to around a hundred thousand years ago. The discovery of modern human remains in a considerable number of prehistoric caves also implies that the population of this island was quite dense during the Early-Mid Holocene. However, our understanding of the early process of human settlement on Java Island is more based on archaeology and palaeoanthropology studies in the southern and central parts of Java Island. Meanwhile, the northern coast of Java Island has not received equal attention. Research to reveal the early human settlement in this area has not been carried out. If any, it is still very limited. Only in the last decade several prehistoric archaeological studies have been conducted on the northern coast of Central Java and East Java (2–13).

In this paper, we present the results of analyses on human teeth recovered in Gua Bedug, one of the sites that has been archaeologically excavated in the Rembang Zone, northern karst area of Java. The analysis focused on the dental metric and morphology of 29 tooth specimens. It is aimed specially to reveal the possible affinity of the population that inhabited this rockshelter in the Early-Mid Holocene. The results of this analysis are expected to add new information and shed light on the early modern human occupation of the north coast of Java during that period.

Before this research, our knowledge about the prehistory of Java Island relied largely on the data collected from Gunung Sewu, a karst region situated on the south coast of Central and East Java. The human inhabitation in the Gunung Sewu karst area can be traced to the Pleistocene, with two deciduous molars from Song Terus dated to 60 and 40 ka (14). Although still debated (15), breccia deposit for Punung fauna assemblage containing a Homo sapiens tooth (16) was assumed to be deposited not later than 118 ka (17). Still on the southern coast of Java, to the east of Gunung Sewu renowned fossils of Wajak were found in the karst of Campurdarat, Tulungagung. The dating for Wajak is more widely accepted, ranging from 37,4 to 28,5 ka (18).

For the Early-Mid Holocene period as the focus of this article, archaeological and paleoanthropological research in Gunung Sewu provides a comprehensive reconstruction of human life in the past, including the human inhabitants, technology, subsistence, beliefs, and paleoenvironment. That research resulted in a wide-ranging dataset and a considerable number of human remains, e.g from Gua Braholo (8 individuals), Song Keplek (5 individuals), and one individual from Song Terus (19,20). Most of these human remains have been analysed in detail by Widianto, Détroit, and Noerwidi (19,21,22). The majority of Early-Mid Holocene human remains from Gunung Sewu exhibit characteristics typical of Australo-Melanesian populations, who now primarily inhabit eastern Indonesia, Papua, and Australia. Radiocarbon dating shows that they occupied Gunung Sewu from the Late Pleistocene to Early-Mid Holocene, between 13,500 to 4,500 BP (20). An exception to this is a Neolithic burial from Song Keplek (SK5) which has been dated to around 3,200 BP (22).

Human skeletal remains were also discovered in the Bandung Basin area, West Java. Excavations at Gua Pawon located on the southern side of the basin, conducted between 2003 and 2018, recovered seven human skeletons along with obsidian tools, bone tools, animal bones, and mollusk shells. Radiocarbon dates for this population range from 5,660±170 uncal. BP, 7,320±180 uncal. BP, and 9,520±200 uncal. BP (23,24). Five of the seven individuals from this site are showing characteristics consistent with Australo-Melanesian populations (22).

Recent archaeological research in the northern region of Central Java, especially in the Rembang Zone karst area (Figure 1), has also succeeded in finding human remains. These findings could shed light on our understanding of human settlement in Java during the Early-Mid Holocene. Presumably, around 12,000 BP a flood on the Sunda Shelf caused by rising sea levels after the Last Glacial Maximum forced the population to move to higher regions (7–9). The north coast of Java which lies closer to the Sunda Shelf was logically inhabited before the south coast. Unfortunately, the lack of thorough archaeological research until the last decade has not been able to shed light on this possibility. With more intensive research in the area, new data are now beginning to emerge.

More systematic archaeological research began with the excavation of Gua Kidang, in the Blora Regency, which succeeded in discovering the first cave burial in the Rembang Zone. These

burials include three individuals positioned in different ways: flexed, sitting, and semi-flexed. Paleoanthropological analysis indicates that all three individuals have similarities to the characteristics of Australo-Melanesian affinity. Meanwhile, pathological analysis revealed that the skeletons suffered from rheumatic disease and had a high degree of attrition on their teeth crowns (9). These human skeletons were in the Preneolithic culture contexts, as indicated by artifacts such as scrapers and points that are mostly made from bone and shell materials. Some of the bones and shells indicate that it was intentionally perforated suggesting they were used as ornaments (7,8). The chronometric data for Gua Kidang is 7,770 ± 220 uncal. BP and 9,440 ± 220 uncal. BP, which was obtained from charcoal samples analysed in the laboratory of Pusat Survei Geologi/ Geological Survey Center, Institut Teknologi Bandung (6,10). The most recent AMS radiocarbon analysis held in Beta Analytic on a molar from one of human remains suggests a younger period of 5,719 – 5,578 BP cal. BP (25).

Meanwhile, archaeological research at Gua Bedug, a rock shelter site in Rembang Regency located approximately 17 km northeast of Gua Kidang, has uncovered a fragmented skull (Figure 2) and isolated teeth, along with bone and shell artifacts (26,27). Similar to Gua Kidang, markers of Preneolithic culture, such as shell scrapers and bone points artifacts were found in one context with these human remains. Pottery fragments are often used as markers for Neolithic culture or modern disturbance in stratigraphy that were not recovered below 20 cm in the excavation units at this site (27).

In the excavation of Gua Bedug, all the human remains were discovered in TP 1 and TP 3 units. These two 1x 1 m units were situated next to each other, forming a 2 x 1 m excavation unit in overall (26,27). In total 29 teeth were discovered isolated or associated with the skull fragments. These dental remains were found starting from a depth of 30 cm to 100 cm below the surface. Gua Bedug has been dated to 6,012-5,895 cal BP and 8,777-8,542 cal BP (25,27). Direct dating was initially attempted on an isolated molar sample, but it was unsuccessful due to insufficient collagen (25).

Considering the available chronometric datings from Gua Kidang and Gua Bedug, there is still not enough evidence to claim that the northern part of Java was inhabited before the southern part due to the rapid flooding of the Sunda Shelf at 12,000 BP (28,29). To this stage, evidence suggests that the population in northern Java during the Early Holocene was younger than in southern Java. The earliest known occupation of the Rembang Zone dates to around 8,700 years ago, while those of the Gunung Sewu area in southern Java were inhabited at least since 12,000 BP (24,30–32). It is important to note, however, that research in the northern karst region of Java is still in its early stages, unlike the southern karst, which has been extensively studied for decades. Future research in the Rembang Zone may yield older dates and further refine our understanding of the prehistoric inhabitation of Java.

The potential of the research in the Rembang Zone underlined the importance of studying their human remains. Knowledge derived from this research will contribute to a better understanding of the relationship between prehistoric populations across different sites in Java, particularly between the northern and the southern regions. Did the same prehistoric populations inhabit both karst areas? This article addresses this question by examining dental records from Gua Bedug, focusing on the affinity identification of the prehistoric populations at this site. From a broader perspective, the article also explores how this new data contributes to our understanding of the chronological context of prehistoric populations in Indonesia, with a particular emphasis on the northern coast of Java.

Material and Methods

Based on previous studies, it is generally assumed that there are at least two layers of population migrations into the Islands of Southeast Asia including Java Island (33,34). The first migration was undertaken by Homo sapiens with Australo-Melanesian affinities as early as the Late Pleistocene, but their most common evidence is from Early-Mid Holocene cave sites. In other publications, this population is also referred to as Australo-Papuan (35). Another migration was carried out by Homo sapiens with East-Asian affinities in Late Holocene. The latter is also referred as Southeast Asian population (36) or Asian Neolithic (35) in other publications. In short, the Australo-Melanesian in this paper represents Homo sapiens population from the Early-Mid Holocene of Indonesia, while the East Asian represents Homo sapiens population from the Late Holocene of Indonesia. In describing the results of this research, we will temporarily follow this assumption and use classifications and

terminology that are commonly applied in this context.

In this study, we examined 29 teeth from Gua Bedug, consisting of 13 molars, 8 premolars, 4 incisors, 3 canines, and 1 indeterminable tooth. This indeterminable tooth is most likely the first molar of the mandible. However, the identification process is difficult because the root has post-mortem fracture, and the severe grade 6 attrition is making it unobservable. This study emphasizes observations of dental characteristics and dental metrics to identify the affinity characteristics of the population in Gua Bedug. Based on observations of the specimens from Gua Bedug, the incisors and molar dental classes show quite clear population affinity characteristics. In contrast, the affinity characteristics in the premolar and canine classes are not as distinctive as the molar and incisor classes. For that reason, the discussion in this article will primarily give attention to incisor and molar dental classes (Table 1). The analysis focused on biological aspects, including the minimum number of individuals (MNI), age, and population affinity.

Table 1. Incisor and molar classes.

No	Code	Unit	Depth interval (cm)	14C Dating association	Class	Siding	Lateral	Digit	Attrition grade	MD (mm)	BL (mm)	Betel stain (molar)	Affinity	Age Estimation	Age Category	Remarks
1	GBDG 1 (4)	TP1	30-40	N/A	I	Sup	Dex	2	1	7,2	6,7	N/A	AM	16-20	Adolescent	Individual 1
2	GBDG 1 (5)	TP1	40-50	6,012-5,895 cal BP	I	Sup	Dex	1	1	8,4	7,6	N/A	AM	16-20	Adolescent	
3	GBDG 3 (5) 2	TP3	40-50	6,012-5,895 cal BP	M	Sup	Sin	1	7	9,6	13,1	Absent	indeterminate	>50	Old adult	
4	GBDG 3 (5) 3	TP3	40-50	6,012-5,895 cal BP	M	Sup	Sin	3	6	10,5	13,2	Absent	indeterminate	>50	Old adult	Individual 2
5	GBDG 3-3	TP3	55-60	6,012-5,895 cal BP	M	Sup	Sin	2	6	10,7	13,1	N/A	indeterminate	>50	Old adult	
6	GBDG 3-10	TP3	40-60	6,012-5,895 cal BP	M	Inf	Sin	2	2	12	12,2	Present	EA	24-30	Young adult	Individual 3
7	GBDG 1 (6) 1	TP1	50-60	N/A	M	Inf	Dex	2	2	12,2	12,2	Present	EA	24-30	Young adult	
8	GBDG 1 (6) 7	TP1	50-60	N/A	M	Inf	Dex	2	0	12,3	11,5	Absent	AM	7	Child	
9	GBDG 1 (6) 8	TP1	50-60	N/A	M	Sup	Sin	1	1	10,5	13,4	Absent	AM	3-4	Child	Individual 4
10	GBDG 1 (6) 9	TP1	50-60	N/A	M	Sup	Dex	2	0	11,2	13,2	Absent	AM	9-10	Child	
11	GBDG 1 (6) 2	TP1	50-60	N/A	M	Sup	Sin	3	2	11,9	13,3	Absent	AM	30-35	Young adult	
12	GBDG 1 (7)	TP1	60-70	N/A	indeterminate				6	-	-	Present	indeterminate	>50	Old adult	
13	GBDG 1 (8) 2	TP1	70-80	8,777-8,542 cal BP	M	Inf	Sin	1	0	12,4	11,6	Absent	AM	5	Child	
14	GBDG 1 (9)	TP1	80-90	N/A	M	Sup	Sin	3	0	9,7	10,8	Present	EA	15-18	Adolescent	
15	GBDG 3 (12)	TP3	85	N/A	M	Sup	Dex	3	0	9,4	11,1	Absent	EA	15	Adolescent	
16	GBDG 3-52	TP3	81	N/A	M	Sup	Dex	1	4	11,4	12,3	Absent	EA	25-30	Young adult	
17	GBDG 3 (14)	TP3	90-95	N/A	I	Sup	Dex	1	2	9,4	8,2	N/A	EA	25-30	Young adult	Individual 5
18	GBDG 3 (15) 1	TP3	95-100	N/A	I	Sup	Sin	2	2	7,6	7,2	N/A	EA	25-30	Young adult	

Note: I=Incisive, M= Molar. Inf=Inferior, Sup=Superior. Sin=Sinistra, Dex=Dextra, MD=Mesio-distal, BL=Bucco-lingual, AM= Australo-Melanesian, EA = East Asian

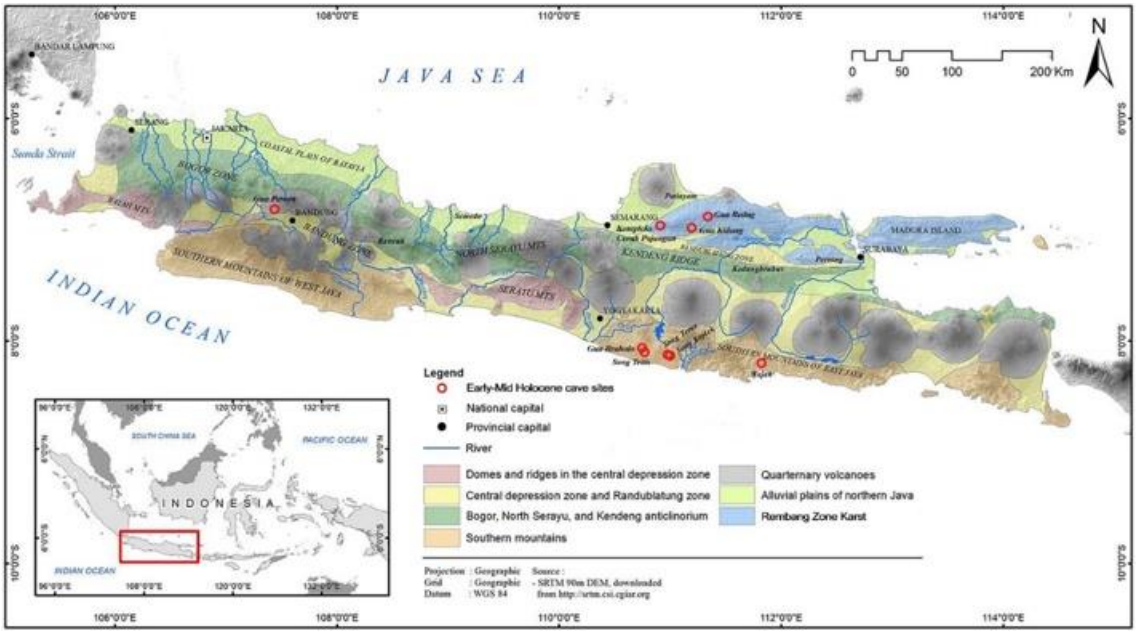

Figure 1. Distribution of prehistoric sites in Java and their respective karst area (Noerwidi, 2020 with modifications).

Figure 2. Side view of Gua Bedug (left) and the fragmented skull recovered during excavation (right) (photographs by Wibowo, 2021).

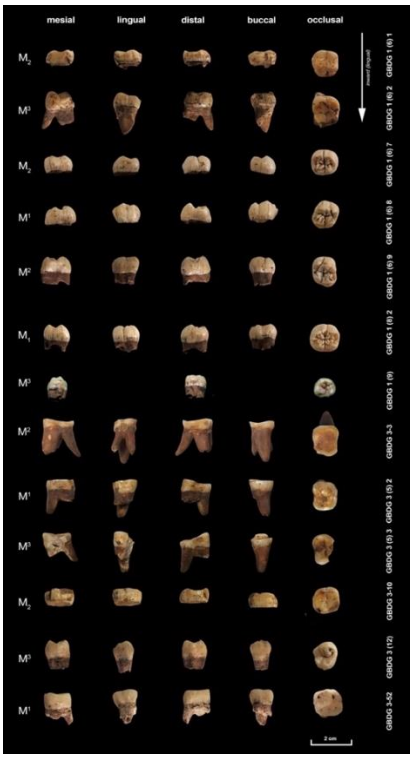

Figure 3. Molars from Gua Bedug, Rembang, Central Java.

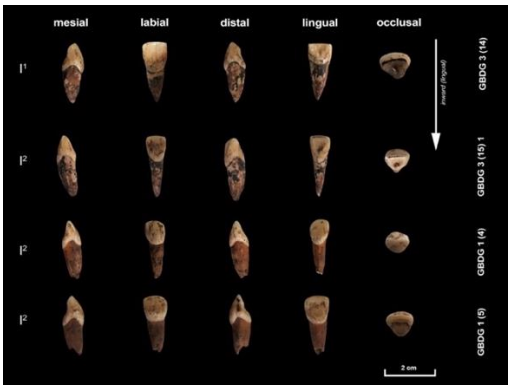

Figure 4. Incisive teeth from Gua Bedug, Rembang, Central Java.

The description of dental characteristics in this study follows the approach by Martinon-Torres et al. (37), with division based on their dental classes and then described by their morphological features. The description of this morphology is primarily on crown characteristics. As an integral part of the crown characteristic, we are using a wear pattern grading system by Molnar (38). The characteristics are identifiable only on teeth that have a wear pattern of less/ equal to the grade 4 (39).

Using their morphology characteristics, comparisons with other prehistoric populations in Indonesia were carried out by Principal Component Analysis (PCA). The comparison database is derived from Noerwidi (24,39,40) which consists dental records of Homo sapiens and Homo erectus from various prehistoric sites

in Indonesia. PCA on molar teeth is using variables: number of cusps, size of C5 (Cusps 5), middle and distal trigonid crest, deflecting wrinkle, crenulation, groove pattern, protostylid, mesial and distal marginal ridge, and anterior and posterior foveas (39). Excluding the Homo erectus, the comparative study for molars involved 34 specimens from prehistoric Homo sapiens populations in the Indonesian archipelago.

The incisors PCA was using eight morphological variables (39), which are: labial convexity, shovel shape, dental tubercle, cingulum interruption groove, lingual fovea, mesial and distal marginal ridge, also marginal interruption groove. In Homo erectus its morphology is very complex, then Australo-Melanesian has a very simple morphological form, while the East Asian are in-between, with prominent characteristics including shovel shape, labial convexity, and dental tubercle. The incisors from Gua Bedug were compared to 25 other specimens, both from Homo sapiens and Homo erectus.

Besides PCA, the metric comparison was carried out by employing bivariate analysis. Bivariate plots are useful to explore the relationship between two variables that have been measured on the same sets of subjects (22). The variables for these dental metrics bivariate analysis was obtained from their MD and BL measurements in millimeters. This metric comparative study was excluding Homo erectus and involving 64 Homo sapiens specimens.

The dental metric measurements in this study are the classical mesio-distal (MD) and bucco-lingual (BL) dimensions of the crown following the methods of Lefêvre (41), with measurement protocol following Martinon-Torres et al. (37). The MD diameter for incisors was measured as the maximum distance between the mesial and distal faces, parallel to the incisal/occlusal surface. The BL diameter of incisors was measured as the maximum width between the buccal and the lingual surfaces of the tooth in a plane that is perpendicular to the MD diameter. For molars, the MD diameter is the maximum distance between the mesial and the distal faces, parallel to the occlusal surface. The reference plane for placement of the fixed calliper tip is the mesial surface since it is usually flatter than the distal surface. For the BL diameter of molars, we measured the maximum width between the buccal and the lingual surfaces, parallel to the occlusal surface. The reference plane for this measurement is usually the lingual surface for the lower molars and the buccal surface for the upper molars (37).

Results

Molar Morphology

Most molar tooth roots are fragile and fractured post-mortem. However, most of their dental crowns tend to be complete and identifiable. Few specimens on their occlusal have significant attrition so the cusps are no longer visible (Figure 3).

GBDG 1 (6) 1: It is the crown of the second molar of the right mandible. The outline of the crown is square-shaped, and the cusps can be divided into two parts through the midline. The root of the tooth was not found due to a post-mortem fracture. The tooth shows five cusps with a trace expression of hypoconulid. Entoconulid and metaconulid is absent. Both the middle and distal trigonid crest are weak but interrupted by a central groove. The groove pattern is in an X pattern with contact between the protoconid and entoconid. The essential ridge in deflecting wrinkles is straight, but with constriction and crenulation, it happens on one cusp area. Only slight linear mesial marginal ridge without any distal marginal ridge. Ridges and marginal ridges are more developed, but the posterior fovea is absent. The buccal pit is present. The level of wear and attrition has already begun to occur, so it can be estimated that this individual has the age at death around 24-30 years old. On the occlusal part, some stains are caused by consuming areca nuts and betel. On the mesio-lingual part, there is a brown supragingival tooth calculus located above the gum line.

GBDG 1 (6) 2: It is a fragment of the third molar from the left maxilla. The four cusps of dental crowns are not the same size. The midline does not symmetrically divide the occlusal, and residues of areca nuts and betel consumption is observable. Post-mortem fractures occur exactly at the border between the crown and roots. There are fractures on the cusps located in the distobuccal (metacone) and the mesiobuccal. This molar also has rhomboid cusps with an irregular position. The metacone is pronounced, the hypocone is developed but smaller in size, and the absent metaconule. Buccal and lingual accessory tubercles are not present. No crenulations can be observed. There is a crest connecting the protocone and metacone, but there is no transversal crest which connects the mesial protocone and the paracone. Cusps such as Carabelli and parastyle cannot be seen on this tooth. A distal margin ridge is absent from this

molar. There are three roots which are the distinctive features of maxilla teeth. Two buccal roots were significantly fractured but the root canal is still visible. Meanwhile, one lingual root was still in good condition. Based on its attrition, it is estimated that this individual was 30-35 years old.

GBDG 1 (6) 7: This is a second molar of the right mandible. It has four cusps with a square shape (rectangular) occlusal outline. The tooth shows no trace of hypoconulid, entoconulid and metaconulid. The middle and distal trigonid crest seems weak and interrupted by central groove. The groove pattern shows a + pattern, and it can be seen cusps one, two, three, and four contacted at the central sulcus. The essential ridge deflects halfway and does not contact the hypoconid. Crenulation cusps can be seen on all cusp area. There is a positive expression on buccal surface. Slight linear ridges can be marked as the presence of mesial and distal margins. There are also essential ridges pronounced and well-developed, which produce the anterior fovea but only slight linear depression in the posterior fovea. This molar was recovered without its roots, not because of a post-mortem fracture, but because it has not yet developed. Based on the development of the crown, this molar is estimated to have come from a 7-years-old individual.

GBDG 1 (6) 8: This is the first molar of the left maxilla, which has a total of four cusps. These tooth cusps are not symmetrical. The metacone is large but the hypocone is normally oval-shaped, and the metaconule is absent. The buccal accessory tubercle is absent but lingual accessory tubercle shows a small tubercle. Crenulation cusps can be seen on two cusps areas. There is an interrupted crest between the protocone and the metacone (Crista obliqua), and also an interrupted crest between the protocone and paracone (transversal crest). Mesial marginal accessories tubercle can be observed, but Carabelli on lingual and parastyle on the cingulum are absent. There a slight linear mesial marginal ridge that can be seen but absent distal marginal ridge. Essential ridges on the trigonid are developed but not produce a definitive fovea on the anterior trigonid. The posterior fovea which is located on the posterior occlusal surface absent. The molar root has not developed and based on the perfectly grown crown of the tooth, it is estimated this molar came from 3-4 years old.

GBDG 1 (6) 9: This is the second molar of the right maxilla, which has an asymmetrical 5 parallelogram-shaped cusps. The metacone is large with hypocone in normal ovate shape and a trace of metaconule. The buccal accessory tubercle is absent, but a slight tubercle in lingual. Crenulation can be seen on two cusps areas. There is a continuous crest connecting the protocone and metacone (Crista Obliqua), but between the protocone and paracone it is interrupted (Transversal crest). Mesial marginal accessories tubercle is present. Carabelli cup is absent but a small parastyle on cingulum near the buccal grove is present. Both mesial and distal marginal ridges are slightly linear. Anterior fovea is visible but not distinctive, meanwhile posterior fovea is only slightly present. The roots of this molar have appeared but are still in the developing stage. Based on the complete development of the crown and the appearance of its roots, the age is estimated to be 9-10 years old.

GBDG 1 (7): This tooth is a fragment of molar, but the exact position cannot be determined due to post-mortem fractures and the high degree of attrition. Only the molar crown can be recovered. The outline of the crown is hardly to be determined. There are brown stains on the occlusal which is a sign of areca and betel nut consumption. Based on attrition, it can be estimated that this individual was over 50 years old.

GBDG 1 (8) 2: This tooth is the first molar of the left mandible. It has seven cusps with no signs of attrition. There is a trace of expression on hypoconulid, cusp six is less than half the size of cusp five, and there is a small cusp between cusp two and four. Both the middle and distal trigonid crest show a weak and is interrupted by the central groove. The essential ridge on the mesiolingual cusp is straight, but it has a constricted midpoint. Crenulation cusps can be seen on all of the cusp's areas. The groove system shows a + pattern contacting the protoconid, metaconid, hypoconid, and entoconid at the central sulcus. A visible small pit is located around the midpoint of the crown on the buccal surface. There is a slightly linear ridge in the mesial and distal sides of the tooth. Pronounced ridges and ridge margin developed, creating a groove on the anterior occlusal surface, and a slight linear depression on the posterior occlusal surface. This tooth has three roots with a post-mortem fracture for the lingual root. Only some parts of the root were grown because this individual was not mature. Based on the dental eruption chart, it can be estimated that this individual is 5 years old.

GBDG 1 (9): This tooth is the third molar of the left maxilla with 5 cusps. The metacone is faint but with a free apex. The hypocone has a size reduction but a normal ovate shape. Meanwhile, the metaconule shows a medium-sized cusp. The buccal accessory tubercle is absent but there is a slight tubercle in lingual. No crenulation can be observed. There are enamel crests between protocone-metacone, and protocone-paracone but both of them are interrupted. The mesial and distal margin has a slight linear ridge without any tubercle. No evidence of Carabelli's cusp and parastyle. The anterior fovea is developed but not in posterior fovea. There are no signs of attrition, and the roots are still in the developing stage. This molar was selected as a sample for AMS radiocarbon dating, which was unsuccessful due to the lack of collagen. There is no abnormality in this molar, and based on the absence of attrition and incomplete roots, it is estimated at an age of 15-18 years.

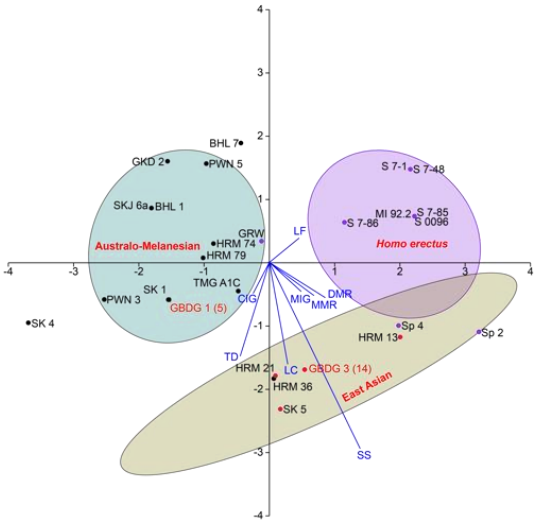

Figure 5. Principal Component Analysis on upper central incisive between Gua Bedug (GBDG) specimens compared to Homo erectus (purple dots), Australo-Melanesian (black dots) and East Asian populations (red dots). Site Codes: BHL: Gua Braholo; GKD: Gua Kidang; GRW: Grogolan Wetan; HRM: Gua Harimau; MI: Miri; PWN: Gua Pawon; S: Sangiran; SK: Song Keplek; SKJ: Sukajadi; Sp: Zhoukoudian; TMG: Tamiang; | Variables: LF: Lingual Fovea; CIG: Cingulum Interruption Groove; TD: Tuberculum Dental; LC: Labial Convexity; MIG: Marginal Interruption Groove; MMR: Mesial Marginal Ridge; DMR: Distal Marginal Ridge; SS: Shovel Shape.

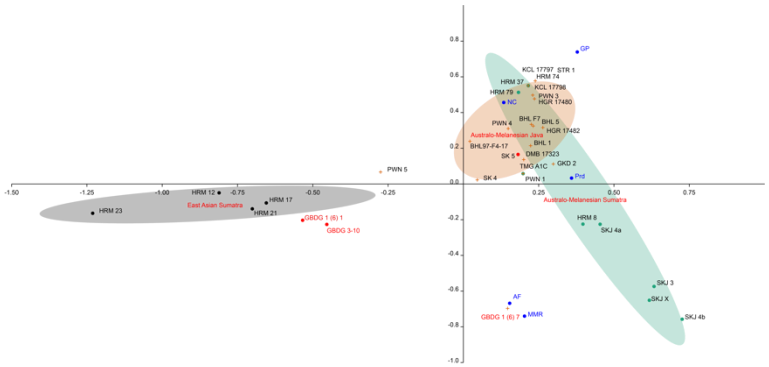

Figure 6. PCA on lower second molar between Gua Bedug (GBDG) specimens compared to Anatomically Modern Human (yellow dots), Australo-Melanesian from Java (orange cross) and Sumatra (green dots), and East Asian from Java (red dots) and Sumatra (black dots). Site Codes: BHL: Gua Braholo; DMB: Gua Djimbe; GKD: Gua Kidang; HGR: Hoekgroot; HRM: Gua Harimau; KCL: Gua Kecil; PWN: Gua Pawon; SK: Song Keplek; SKJ: Sukajadi; ST: Song Terus; STR: Song Tritis; TMG: Tamiang | Variables: C5: Cusps 5; MdTC: Middle Trigonid Crest; NC: Number of Cusps; GP: Groove Pattern; DTC: Distal Trigonid Crest; AF: Anterior Fovea; MMR: Mesial Marginal Ridge; Prd: Protoconid; PF: Posterior Fovea; DMR: Distal Marginal Ridge.

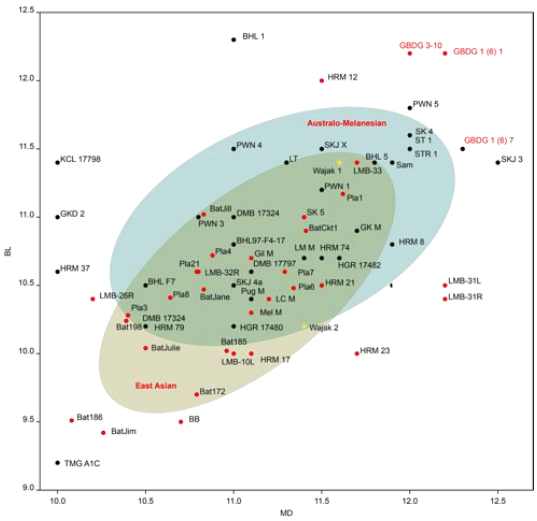

Figure 7. Comparison of the Mesio-Distal vs Bucco-Lingual diameters of the second lower molars from Gua Bedug (GBDG) specimens with Australo-Melanesian (black dots) and East Asian populations (red dots). Site Codes: Bat: Batujaya; BHL: Gua Braholo; BB: Bola Batu; DMB: Gua Djimbe; Gil: Gilimanuk; GK: Gua Kepah; GKD: Gua Kidang; HGR: Hoekgroot; HRM: Gua Harimau; KCL: Gua Kecil; LC: Leang Cadang; LM: Leang Momer; LMB: Lambanapu; LT: Leang T; Mel: Melolo; MSU: Gua Mesiu; Pla: Plawangan; Pug: Puger; PWN: Gua Pawon; Sam: Sampung; SK: Song Keplek; SKJ: Sukajadi; ST: Song Terus; STR: Song Tritis; TMG: Tamiang.

GBDG 3 (5) 2: This tooth is the first molar of the left maxilla. It has three roots. Two roots in the lingual part were broken post-mortem, and one root in the buccal part is more robust than usual. The crown is a trapezoid, but the traces of cusps are no longer visible because of the advanced level of attrition. Based on this attrition, it can be estimated that this individual is over 50 years old.
GBDG 3 (5) 3: This tooth is the third molar of the left maxilla. From the occlusal outline, it can be seen that this tooth has an irregular shape with a rounded lingual. Although attrition has entered an advanced stage, one cusp is still visible in the lingual. There are post-mortem fractures in the buccal roots and mesial crown. Moreover, dental calculus can be seen in the buccal part of the crown. Based on tooth attrition, it can be estimated that the age at death is more than 50 years.
GBDG 3 (12): This tooth is the third molar of the right maxilla. Based on morphology it can be seen that it has larger size than the premolars but is still smaller than the first and second molars. This tooth has five cusps with metaconule. Based on observation it can be seen that it has a weak metacone cusp. The hypocone is in moderate size and the metaconule is in medium cusp. Buccal and lingual accessory tubercles are absent. Crenulation cups can be seen on two cusps areas. Both crista oblique and transversal crest are absent. There is a slight linear in the mesial marginal ridge without any mesial marginal accessories tubercle. Distal marginal ridge is also absent. Carabelli's cusp and parastyle are absent. The anterior fovea is developed but the posterior fovea is absent. Three roots are still in the developing stage and likely will be fused into one. The crown is intact without any attritions, it is estimated that this individual was 15 years old.
GBDG 3-3: This tooth is the second molar of the left maxilla and has three roots. Buccal roots are more robust than normal. Tooth crown has heavy attrition and age at death estimated is more than 50 years old.
GBDG 3-10: This is the second molar of the left mandible. The occlusal outline is square-shaped and the distal side of the crown has heavy attrition. The tooth shows no hypoconulid, entoconulid and metaconulid. A crest connecting the protoconid and metaconid can be seen on the mesial side but weak on the distal side. The deflecting wrinkle is absent, and crenulation can be seen on one cusp area. The groove pattern shows an X pattern with contact between the protoconid and entoconid. There is a small pit situated around the midpoint of buccal side of the crown. There is a slight linear ridge, which can be marked as a mesial margin but is absent on the distal. The anterior fovea can be seen only as a trace but the posterior is absent. In the distolingual, there is a chipping that occurs in the

antemortem. The occlusal surface looks brown due to areca and betel nut consumption. Based on the attrition, it is estimated that this individual was 24-30 years old.
GBDG 3-52: It is the first molar of the right maxilla with three roots and 5 cusps. The metacone is large with well-developed hypocone, but only a slight conule for the metaconule. Buccal and lingual accessory tubercles are absent. Both mesial and distal margin shows a slight linear ridge without any tubercle. Buccal and lingual surfaces are smooth therefore no evidence of Carabelli's cusp and parastyle. There is a developed ridge trigonid but not produce a distinctive fovea. Meanwhile, in the distal marginal complex, there is a slight linear depression which can be identified as posterior fovea. There is no dental calculus, but there are brown colors in several parts of this tooth that might be traces of calculus that have been removed post-mortem. The roots also have post-mortem fractures. Two roots in the buccal were completely lost, and one root in the lingual is only partially. Based on the attrition it can be estimated that this individual was 24-30 years old.

Incisor Morphology
Unlike the molars, the four incisors from Gua Bedug are discovered in intact condition. All the specimens have traces of attrition (Figure 4).
GBDG 1 (4): This is the second incisor of the right maxilla with a flat labial surface. The dental attrition is not significant. The mesiodistal length reaches more than half the height of the crown. The size of the roots tends to be elongated, which differentiates this tooth from the first incisors. The morphology of the tooth shows that the labial surface is flat. It is chisel-like because there are no marginal ridges and no lingual fossa. Smooth cingulum without interruption groove. There is also no evidence of mesial and distal marginal ridges and no marginal interruption groove on each marginal ridge. This incisor was fully grown and without attrition, it is estimated that the individual was 16-20 years old. There are no traces of dental calculus on the tooth. If irradiated, there is a fine line that indicates the presence of hypoplasia enamel on these teeth.
GBDG 1 (5): This is the first incisor of the right maxilla with fully grown root that was fractured post-mortem at the tip. The mesiodistal length on the crown exceeds half the height of the teeth. The root is short in proportion compared to the crown. The tooth shows a trace of convexity on the labial surface with a faint shovel shape. The cingular on the lingual surface is smooth without any interruption groove. Lingual fossa and mesial and distal marginal ridge are absent. There is also no evidence of a marginal interruption groove on both marginal ridges. There is an early tooth attrition on the occlusal surface, which concludes that this individual age at death is 16-20 years.
GBDG 3 (14): This is the first incisor of the right maxilla. This specimen was recovered in intact condition. The dimension of the crown tends to be wide, while the root is short in proportion compared to the crown. The labial surface shows moderate convexity and a moderate shovel shape. No tuberculum dental expression in the lingual surface and also no cingulum interruption groove. It can be seen that there is the lingual fossa present on the lingual surface, and also the mesial and distal marginal ridge. However, the interruption groove which is located on the marginal ridge is absent. These incisors are fully grown and have low attrition, indicating that the individual was between 25 and 30 years. Traces of dental calculus are observable on the labial side.
GBDG 3 (15) 1: This is the second incisor of the left maxilla, with the mesiodistal proportion of the crown is more than half the total height of the crown. The root is intact, and its proportion is longer compared to the crown. The tooth shows a weak convexity on the labial surface with a moderate shovel shape and a slightly pronounced mesial and distal marginal ridge. The tuberculum dental shows faint ridging and an interruption groove. The lingual fossa is also present, but no marginal interruption groove can be seen on the marginal ridge. This incisor is fully grown and has low attrition, which indicates the age at death approximately 25-30 years old. On the labial side, there are traces of dental calculus.

Discussion
Previous studies have demonstrated that the third maxillary molar is effective in determining the Minimum Number of Individuals (MNI) and estimate the age of the individual (42). The third upper molar exhibits significant morphological variability between individuals, making it a reliable marker for distinguishing different people (43). We observed four specimens of the third upper molar teeth out of 13 molar teeth (Table 1). From these four specimens, three of them are left maxillary molars indicating that these left maxilla M3 belong to three different adult individuals. Additionally, specimens in the growth stage were observed, lacking a fully developed third molar,

suggesting the presence of at least one child. Thus, at least four individuals are represented in the dental records from Gua Bedug.

Furthermore, using the third maxillary molar, the degree of attrition on the occlusal surface can help determine an individual's age, as noted by Molnar (38). The three individuals from Gua Bedug have degrees of attrition level 0 (eruption), 2 (early), and 6 (advanced). Based on the age category defined by Aftandilian et. al. (44), the estimated age of the three adult individuals ranges from adolescents (12-20 years), young adults (21-35 years), and old adults (> 55 years). The estimated age of the individual child ranges from 10 ±2.5 years based on the second molar tooth of GBDG 1 (6) 7 condition that is still in the eruption stage.

Based on archaeological context, the number of individuals at this site is more than the number suggested by their M3. Two incisors, GBDG 1 (4) and GBDG 1 (5), discovered 30-40 cm below the surface were probably representing one individual. In the depth below these two teeth a fragmented skull from different individual was discovered, with a premolar (GBDG 3-2) still in the maxilla. Based on this premolar we can associate three isolated molars with the skull, they are GBDG 3 (5) 2, GBDG 3 (5) 3, and GBDG 3-3. The context for this skull was dated to 6,012-5,895 cal BP, obtained from charcoal sample in a depth of 56 cm (25,27). Six other isolated teeth were discovered in the depth interval of 40-60 cm that might represent at least two other individual, including a child. In these isolated teeth stain of betel and areca nut consumption is present in two molars, GBDG 3-10 and GBDG 1 (6) 1. Current hypothesis suggests pre-Austronesian origin of betel nut consumption from the Indo-Malaysian region (45). The specimens from Gua Bedug can support this hypothesis. Furthermore, other recent discovery of a burial dated to 11,639 - 11,277 cal BP at Gua Batu Baras, Kalimantan with betel stain in the dentition also support this hypothesis (46).

Two other specimens with betel stain were discovered below the horizon of the fragmented skull. An indeterminable tooth of GBDG 1 (7) was discovered from depth 60-70 cm depth interval, and M3 of GBDG 1 (9) was discovered from 80-90 cm depth interval. Between these two specimens, an isolated molar of GBDG 1 (8) 2 that might represent a second child individual from this site was discovered from a depth interval of 70-80 cm. In the same horizon with this child's molar, mollusk shell assemblage was dated to 8,777-8,542 cal BP (25,27) using sample of a Unionidae freshwater mollusk. Therefore, we can suggest that the indeterminable tooth of GBDG 1 (7) should be older than 5,800 BP and younger than 8,500 BP. For GBDG 1 (9) and four other isolated teeth that were discovered below the 80 cm horizon, currently there is no radiocarbon dating available. But, we can suggest that they should be older than 8,500 BP.

Incisor Morphology

There are two types of incisor morphology in Gua Bedug, shovel and blade shape. Shovel-shaped characters are very commonly found in East Asian populations. Meanwhile, blade-shaped incisors with simpler morphology usually can be found in Australo-Melanesian populations. In Gua Bedug, the shovel-shaped character is found in two incisors, which are GBDG 3 (14) and GBDG 3 (15) 1. Based on the grading system, the shovel shaped on these two incisors is included in the semi-shovel category (44) or moderate shovel shape (39). Their marginal ridges are more pronounced, and there is a tendency for ridge convergence. Thus, it can be ascertained that these two incisors are related to the East Asian affinity.

The other two incisors from the Gua Bedug collection, GBDG 1 (4) and GBDG 1 (5) are showing characteristics of Australo-Melanesian affinity. GBDG 1 (4) has blade-shaped tooth or no shovel-shaped, their marginal ridges are not expressed, and the labial surface is flat. Although GBDG 1 (5) has a shovel-shaped character that belongs to the faint shovel-shaped category (39,44), only very slight elevations of mesial and distal aspects of the lingual surface can be seen and palpated. Therefore, we assume that this specimen is closer to a blade shape morphology rather than a shovel.

The result of PCA on the first upper incisors confirmed that GBDG 1 (5) came from the Australo-Melanesian population, and GBDG 3 (14) from the East-Asian population (Figure 5). It is interesting to note that these two specimens from the northern coast of Java are close to the Song Keplek specimen from the southern coast of Java. The variables possessed by GBDG 1 (5) are close to the SK1 specimen, which has a site dating of 8,000 – 4,500 years ago (21), while GBDG 3 (14) is close to the SK5 specimen which has a dating of 3,200 BP (22). Although it cannot be directly compared, the second incisor of GBDG 3 (15) has the same shovel-shaped grade as GBDG 3 (14). Thus, GBDG 3 (15) is also likely to have a close affinity to SK5. The second

(lateral) upper incisors cannot be compared because the specimen for comparison is limited.

Molar Morphology

It has been known that molar morphology can be used to distinguish populations. Australo-Melanesian populations have more simple molar teeth than East Asian populations. The upper molar of the Australo-Melanesian population has only four major cusps (in the absence of C5), while the East Asian population usually has five major cusps, with a significant size of C5 (24,39). For the lower molar, Australo-Melanesian and East Asian populations usually have more than four cusps. These cusp variations can be influenced by genetic factors, environmental factors, and evolutionary changes over time (44). In the lower molar, the difference between the Australo-Melanesian and East Asian populations is the groove pattern. The Australo-Melanesian population has a "+" groove pattern with all cusps joined in the middle of the central groove, and the East Asian population has a "Y" groove pattern which is more complex and complemented by the middle and distal trigonid crest (24).

From the total 13 molars, there were 3 specimens whose affinity could not be identified due to the high attrition (grade 6-7). These three specimens are the molars associated with the skull, they are GBDG 3-3, GBDG 3 (5) 2, and GBDG 3 (5) 3. Other 10 molars that can be identified are showing characteristics of East Asian affinity (5 specimens) and Australo-Melanesian (5 specimens).

Two populations are reflected in the four lower molars of the Gua Bedug collection. The groove pattern Y, with contact between cusps 2 (Metaconid) and 3 (Hypoconid) was observed in specimens GBDG 1 (6) 1 and GBDG 3-10. It suggests that these two specimens are from East Asian populations. The groove pattern + showing the Australo-Melanesian populations was visible in GBDG 1 (6) 7 and GBDG 1 (8) 2 specimens. In these two specimens, contact between cusps 1 (Protoconid), 2 (Metaconid), 3 (Hypoconid), and 4 (Entoconid) at the central sulcus was present.

In terms of upper molars, GBDG 1 (9), GBDG 1 (6) 9, GBDG 3 (12), and GBDG 3-52 exhibit the morphological character of the East Asian population. These four specimens have 5 cusps, with clear metaconule appearances in GBDG 1 (9) and GBDG 3 (12), and faint in GBDG 3-52 and GBDG 1 (6) 9 specimens. The upper molar of the Australo-Melanesian population is represented by specimens GBDG 1 (6) 2, and GBDG 1 (6) 8, with four cusps. On these two molars their C5 trait is absent, only one vertical groove on the distal surface of the upper molar between hypocone and metacone.

The PCA result show that the GDBG 1 (6) 7 specimen belongs to the Australo-Melanesian populations but distinctively far from the majority of the dataset, for example with the prehistoric humans of Gua Kidang, Pawon, and Song Keplek in the island of Java (Figure 6). Interestingly, the GDBG 1 (6) 7 specimen is closer to the Australo-Melanesian population of from Sukajadi on the island of Sumatra, with pronounced distal marginal ridge and posterior fovea characteristics. Furthermore, East Asian specimens of GBDG 1 (6) 1 and GBDG 3-10 are also seen closer to a site from Sumatra, the Gua Harimau. The East Asian specimens from Gua Bedug are distinct from SK5, the other East Asian specimens from Java which interestingly based on PCA results fall in the range of the Australo-Melanesian. The results of this comparison might show high variability in one population that inhabits karst mountains on the northern coast of Java.

Dental metric bivariate analysis

Dental metrics in previous studies (22,24,39,40,47–49) show that the second lower molar is reliable for determining population affinity trends by comparing them between populations. Metric comparisons indicate that the second lower molar of Australo-Melanesian populations is generally larger than that of East Asian populations (24). However, in this study, we observe that the majority of the metrics overlap between morphologically defined East Asian and Australo-Melanesian populations (Figure 7). Therefore, it is not probable to define population affinity based only by their MD-BL metrics. But, assessing these metrics with their morphological PCA might be useful in case of specimens that are distinct from the rest of the population.

For example, the GBDG 1 (6) 1 and GBDG 3-10 which are morphologically assigned to East Asian, their metrics are significantly larger than the general second lower molar size of East Asian or even Australo-Melanesian population. These two specimens in the morphology PCA are noted close to the East Asian specimens from Gua Harimau. In the metrics comparison we can observe that HRM 12 also has metrics that are distinct, similar with Gua Bedug specimens. This might infer further relatedness between the two sites, in Java and Sumatra.

The other lower second molar from Gua Bedug, GBDG 1 (6) 7, is morphologically assigned to Australo-Melanesian and their metrics might support the idea that the Australo-Melanesian lower second molar size is larger than East Asian (24). In the metrics comparison this specimen falls closer to SKJ 5, a specimen from the Sukajadi site. Although the morphological PCA also indicating possible relation between these two sites, both specimens are closer to the majority Australo-Melanesian population which is overlapping with the East Asian. Therefore comparative interpretation of this specimen cannot be drawn with confidence.

Conclusion

While metrics comparisons are showing less distinction between prehistoric population of Indonesia, based on dental morphology we are able to identify Australo-Melanesian and East Asian characteristics among the individuals from Gua Bedug. Morphology comparison of the upper and lower incisors representing Australo-Melanesian and East Asian characteristics that are related closely to the prehistoric populations from the southern coast of Java. From the morphology comparisons of the molars, this site shared Australo-Melanesian and East Asian similarities with the prehistoric population in the island of Sumatra. Gua Bedug specimens' similarities with sites that are distantly apart, and their discrepancy with Gua Kidang in the same karst area, are potentially reflecting high variability among prehistoric populations along the north coast of Java.

Apparently, the evidence provided by this study suggests that the settlement process on the northern coast of Java is slightly differ to that of the southern coast during the Early-Mid Holocene. The Preneolithic culture of Gunung Sewu sites in the southern part of Java which are dated between 13,500 - 4,500 BP was solely inhabited by population with Australo-Melanesian affinity. Meanwhile, evidence from Gua Bedug dating back to 5800 BP or Preneolithic period suggests also the existence of a population carrying East Asian characteristics. The presence of East Asian characteristics at Gua Bedug dental records might indicate a process of interbreeding between Australo-Melanesian and East Asian prehistoric population, resulting the presence of both population characteristic in the dental records at this site. Another possibility is that they co-exist during the Preneolithic. Nevertheless, it means that East Asian dental characteristics were present in the northern coast of Java Island earlier than assumed before. Therefore, the dental evidence from the Gua Bedug indicates that in the northern part of Java, the East Asian dental characteristic are not exclusively associated with Neolithic culture. Certainly, this conclusion, based solely on the dental metrics and morphological observation, still needs to be confirmed through further research with more consideration of the taphonomic process and direct dating on the samples. Unfortunately, previous direct dating was unsuccessful. In any case, the results of this study suggest that the settlement on the island of Java following the sea level rise around 12,000 BP are more complex than previously thought.

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Declaration of Interest

None

Author Contribution

HW designed and lead the research, collected the data, contributed to the map, documentation, and wrote the initial manuscript. SN contributed to the map, data description, analysis, and wrote the initial manuscript. DAT supervised all the process, contribute to the introduction, and provides substantial inputs for the analysis and conclusion. AP contributed to the data description, analysis, and wrote the initial manuscript. NMEF contributed to the data description and wrote the initial manuscript. CR supervised all the process, provides substantial inputs, and edit the initial manuscript. All authors have reviewed, revised, and proofread the final manuscript.

Statement on the use of artificial intelligence in manuscript preparation

Artificial intelligence was not used in the preparation of this manuscript.

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